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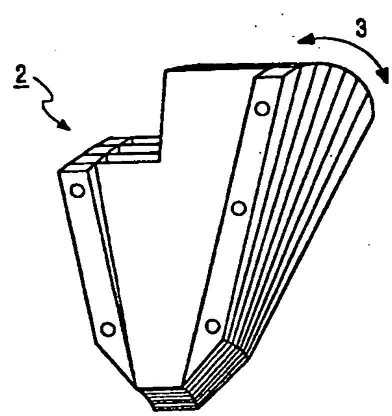

(57) Abstract

The invention relates to an apparatus suited, for example, for extreme ultraviolet lithography, comprising a radiation source and a processing organ for processing the radiation from the radiation source. Between the radiation source and the processing organ a filter is placed, which in the radial direction from the radiation source, comprises a plurality of foils or plates.

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FILTER FOR EXTREME ULTRAVIOLET LITHOGRAPHY

The invention relates to an apparatus comprising a radiation source and a processing organ for processing the radiation from the radiation source.

Such an apparatus may be used in the production of integrated circuits, that is to say in a lithographical application. The invention may also be applied in various other fields. For a good understanding of the invention, however, a lithographical application will serve well as illustration. Continuous attempts are made to make integrated circuits smaller and smaller in order to improve the processing speed of the integrated circuits.

According to the prior art, such integrated circuits are manufactured chiefly by using lithography with visible and ultraviolet light. With these known technologies, it is possible to manufacture integrated circuits that may be as short as 120 nanometres. The ultraviolet light used with said circuits has a wavelength of 193 nanometres. The known techniques do not allow a further decrease of the dimensions of the integrated circuits, and a possible solution is the use of lithography on the basis of extreme ultraviolet light. Such light has a wavelength of 13 nanometres. The known optical elements cannot be used at this wavelength. The known mirrors and lenses absorb too large a portion of the extreme ultraviolet light. In order to allow for this, the processing organ for processing the radiation from the radiation source is a multi-layer mirror which consists of 40 or more molybdenum layers alternating with silicon layers.

In such an apparatus for extreme ultraviolet lithography a laser plasma source is used to generate a plasma by heating an object by means of a laser source of high energy density, for example of at least 10^{11}W/cm^2. The

object heated by the laser will function as source of secondary emission of mainly shortwave radiation. However, this will also release undesirable particles and atoms producing the effect of debris in the apparatus. The objective of the invention is to prevent the production of said debris.

WO 96/10324 discloses such an apparatus for the generation of radiation. This apparatus uses a fast rotating target which is heated by the laser source and which produces the secondary emission. Due to the kinetic energy of the particles formed from the plasma on the rotating target, this apparatus has a filtering effect in respect of the so-called macro-particles. However, trapping atoms and in particular the fastest micro-particles, is not possible in this known apparatus.

According to the invention this possibility is now provided, by the apparatus being characterized in that a filter is placed between the radiation source and the processing organ which filter, in the radial direction from the radiation source, comprises a plurality of foils or plates. Surprisingly it has been shown that this very simple measure not only makes it possible to trap atoms and micro-particles, but also clusters of such micro-particles, respectively the smallest macro-particles.

A first preferred embodiment of the apparatus according to the invention is characterized in that the foils or plates are positioned in a honeycomb construction.

A second preferred embodiment of the apparatus according to the invention is characterized in that the foils or plates are cone-shaped and are positioned concentrically.

Preferably, in the radial direction the foils or plates are positioned such as to be evenly distributed in relation to one another.

Such an apparatus is used with a buffer gas in which the radiation source and the processing organ are placed. Appropriately, the distance between the radiation source and the filter's proximal end in relation to the

radiation source is then selected subject to the pressure and the type of buffer gas. A very suitable choice of buffer gas is krypton, whose pressure is 0.5 Torr, and the distance between the radiation source and the proximal end of the filter is 5 cm. This setting affords sufficient opportunity for the particles to be trapped in the filter to take on the temperature of the buffer gas, for example room temperature, thereby sufficiently reducing the particle's velocity before it enters the filter.

It is further desirable to select the length of the filter, which is formed by the distance between the filter's proximal end and its distal end in relation to the radiation source, subject to the pressure of the buffer gas and the form of the filter. Especially the gas pressure determines the mean free path length for the particles to be trapped; a lower gas pressure corresponds to an increased free path length. This can be partially compensated by the form of the filter. For example, using the above-mentioned honeycomb construction provides a larger surface area, affording greater opportunity for the particles to actually be trapped.

It has been shown that good results can be obtained when the length of the filter is at least 1 cm. This filter length corresponds with a usual gas pressure of, for example, 100 mTorr.

As already mentioned above, the apparatus is operational at room temperature. The measure of maintaining the filter at a temperature which is approximately below room temperature, allows the residence time of the atoms and particles trapped on a foil or plate to be increased, and accordingly the effectiveness of the filter to be improved.

It is further desirable that the number of plates in the filter should be adjusted subject to the thickness of each plate and the desired optical transparency of the filter as determined by the formula

$$\frac{d}{d + d_f} \times 100\ \%$$

in which d = the distance between two plates of the filter at the side of the radiation source; and

d_f = the thickness of a plate of the filter.

In this way the light output of the integral apparatus can be maintained at an adequate level, while the effectiveness of the filter can still be 100%. The apparatus is then preferably characterized in that the number of plates is adjusted such that the distance between two plates is approximately 1 mm.

The effectiveness of the filter may be improved further by roughening the surface of the plates.

The invention is further embodied in a separate filter for suppressing undesirable atomic and microscopic particles emitted by a radiation source, characterized by a plurality of plates positioned substantially parallel in relation to one another, for trapping atomic and microscopic particles on their respective surfaces.

Such a separate filter is preferably characterized in that the plates are directed radially from an imaginary point. This makes it ideal for use in association with a point-like radiation source.

The invention will now be explained in more detail with reference to the drawing, in which

Fig. 1 shows schematically a radiation source together with a filter according to the invention;

Fig. 2 shows a preferred embodiment of the filter according to the invention; and

Fig. 3 shows schematically two more preferred embodiments of the filter according to the invention.

In the Figs., identical reference numbers relate to similar parts.

Fig. 1 shows a radiation source indicated by reference number 1, and a filter which is generally indicated by reference number 2. The processing organ that is used in the apparatus for, for example, extreme ultraviolet lithography, is not shown. This processing organ is located at the side of the filter 2 facing away from the radiation source 1. The filter 2 comprises a number of plates 3 positioned in a radial direction from the radi-

ation source 1. It is possible to position said plates in a honeycomb construction, or as a plurality of concentrical cones as shown in Fig. 3.

Figs. 1 and 2 show that in the direction of radiation from the source 1, the plates are positioned such as to be evenly distributed next to one another. The proximal end 4 of the filter 2 is at a distance X from the radiation source 1, which distance is selected depending on the pressure and the type of buffer gas in which the radiation source 1, the processing organ (not shown), and also the filter 2, are placed. If the apparatus is used for extreme ultraviolet lithography, the buffer gas is preferably krypton having a pressure of 0.5 Torr, and the value of X may be 5 cm. The length of the plates of the filter is indicated by L. The value of L is selected depending on the pressure of the buffer gas and the form of the filter 2. The value of L, that is to say the length of the filter, is at least 1 cm. In Fig. 1, this value is approximately 10 cm. The thickness of the plates 3 may be, for example, 0.1 mm, and the spacing between the plates at the side nearest the radiation source 1, may be approximately 1 mm. This may result in an optical transparency of the filter 2, which is determined by the formula

$$\frac{d}{d + d_f} \times 100\ \%$$

in which d = the distance between two plates of the filter at the proximal side of the filter; and

d_f = the thickness of a plate of the filter.

The effectiveness of the filter can be promoted if the surface of the plates 3 is slightly roughened.

When the apparatus is used for extreme ultraviolet lithography, radiation is used having a wavelength of 13.5 nanometres. Various inert gasses may be used as buffer gas, such as helium and krypton which, compared with other gasses have the lowest absorption coefficient at this wavelength. Krypton is better able to meet the requirements of the present application because the atomic mass of krypton is more compatible with that of the atomic- and

micro-particles emitted by the radiation source, which augments the inhibition of said undesirable particles. The krypton gas used is maintained at a pressure of at least several mTorr. It should be noted that taken over a distance of 20 cm at a pressure of 0.5 Torr, the optical transparency of krypton for the desired radiation is approximately 90%. The filter used in the apparatus is comprised of copper plates (other materials are also possible) which have a length of 7 cm and are positioned at 2 cm from the radiation source. At a plate thickness of 0.2 mm and with the plates being spaced at approximately 0.8 mm at the side of the radiation source, the filter will have a geometrical transparency of approximately 80%. The effectiveness of the filter was measured at room temperature and at a temperature of approximately -90°C. At both these temperatures the effectiveness of the filter was shown to be very high, almost 100.

It will be clear to the person skilled in the art that the various dimensions of the filter forming part of the apparatus according to the invention, as well as the distance from the filter to the radiation source, has to be determined in practice on the basis of the above-mentioned inter-relating ratios. It is therefore possible to apply diverse variations to the above description, without departing from the idea of the invention as specified in the appended claims.

CLAIMS

1. An apparatus suited, for example, for extreme ultraviolet lithography, comprising a radiation source and a processing organ for processing the radiation from the radiation source, **characterized** in that a filter is placed between the radiation source and the processing organ which filter, in the radial direction from the radiation source, comprises a plurality of foils or plates.

2. An apparatus according to claim 1, **characterized** in that the foils or plates are positioned in a honeycomb construction.

3. An apparatus according to claim 1, **characterized** in that the foils or plates are cone-shaped and are positioned concentrically.

4. An apparatus according to one of the claims 1-3, **characterized** in that in the radial direction the foils or plates are positioned such as to be evenly distributed in relation to one another.

5. An apparatus according to one of the claims 1-4, wherein the radiation source and the processing organ are placed in a buffer gas, **characterized** in that the distance between the radiation source and the filter's proximal end in relation to the radiation source is selected subject to the pressure and the type of buffer gas.

6. An apparatus according to claim 5, **characterized** in that the buffer gas is krypton, that the pressure is at least approximately 0.1 Torr, and the distance between the radiation source and the proximal end of the filter is 5 cm.

7. An apparatus according to one of the preceding claims, **characterized** in that the length of the filter, which is formed by the distance between the filter's proximal end and its distal end in relation to the radiation source, is selected subject to the pressure of the buffer gas and the form of the filter.

8. An apparatus according to claim 7, **characterized** in that the length of the filter is at least 1 cm.

9. An apparatus according to one of the preceding claims, **characterized** in that the filter is maintained at a temperature which is below room temperature.

10. An apparatus according to one of the claims 1-9, **characterized** in that the number of plates in the filter is adjusted subject to the thickness of each plate and the desired optical transparency of the filter as determined by the formula

$$\frac{d}{d + d_f} \times 100\ \%$$

in which d = the distance between two plates of the filter at the proximal side of the filter; and

d_f = the thickness of a plate of the filter.

11. An apparatus according to claim 10, **characterized** in that the number of plates is adjusted such that the distance between two plates is approximately 1 mm.

12. An apparatus according to one of the preceding claims, **characterized** in that the surface of the plates is rough.

13. A filter for suppressing undesired atomic and microscopic particles which are emitted by a radiation source, **characterized** in that a plurality of plates are positioned substantially parallel in relation to one another, for trapping atomic and microscopic particles on their respective surfaces.

14. A filter according to claim 13, **characterized** in that the plates are directed radially from an imaginary point.

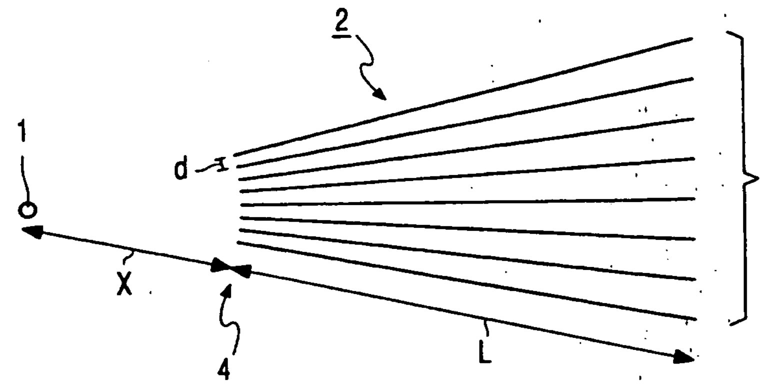

FIG. 1

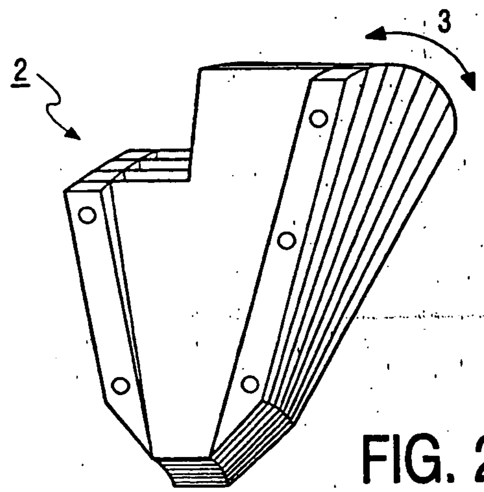

FIG. 2

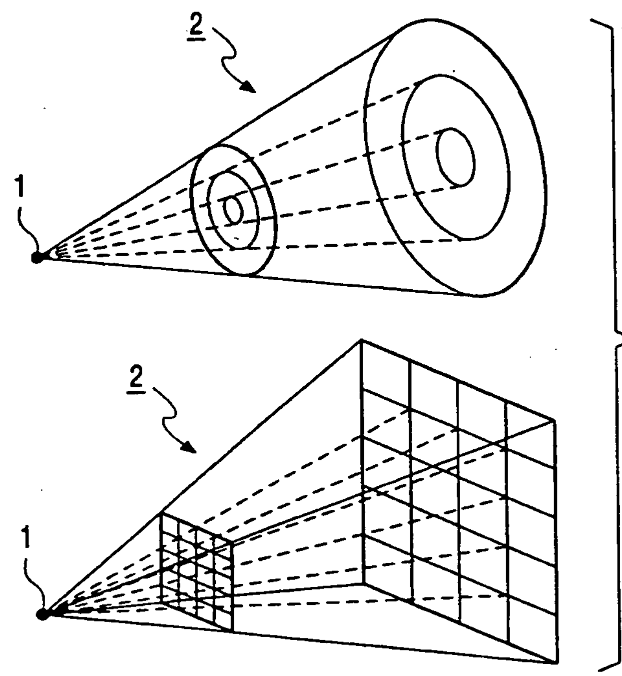

FIG. 3

INTERNATIONAL SEARCH REPORT

International Application No
PCT/NL 99/00090

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G03F7/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G03F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	VARTANIAN M ET AL: "POLYCAPILLARY COLLIMATOR FOR POINT SOURCE PROXIMITY X-RAY LITHOGRAPHY" JOURNAL OF VACUUM SCIENCE AND TECHNOLOGY: PART B, vol. 11, no. 6, 1 November 1993, pages 3003-3007, XP000423451 see page 3003, right-hand column, last paragraph; figures 2,3 ---	1,3,4, 13,14
X	US 4 837 794 A (RIORDAN JOHN C ET AL) 6 June 1989 see column 2, line 55 - column 3, line 2 see figure 3 ---	1,3,4, 13,14

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 242 588 A (SILK JOHN K ET AL) 30 December 1980 see column 5, line 51 - column 6, line 3 see figure 2 ---	1,13,14
X	PATENT ABSTRACTS OF JAPAN vol. 095, no. 010, 30 November 1995 & JP 07 180042 A (NEC CORP), 18 July 1995 see abstract; figure 2 ---	13,14
X	"COLLIMATOR FOR X-RAY LITHOGRAPHY" IBM TECHNICAL DISCLOSURE BULLETIN, vol. 33, no. 4, 1 September 1990, page 278/279 XP000106428 see the whole document -----	13

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Inte onal Application No
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4837794 A	06-06-1989	CA 1233918 A	08-03-1988
		EP 0182477 A	28-05-1986
		JP 61158656 A	18-07-1986
US 4242588 A	30-12-1980	DE 3001059 A	26-02-1981
		JP 1163073 C	10-08-1983
		JP 56027930 A	18-03-1981
		JP 57053657 B	13-11-1982